4th URSI Austria Meeting

Planetary radio astronomy by space-borne and ground-based low-frequency observations

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Commission for Astronomy
Austrian Academy of Sciences
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UTR-2, June, 2015

Konovalenko et al., 2015

Ukrainian decameter radio telescopes

Radio telescope	Allocation	Frequency range, MHz	Maximal effective area, m^2	The number of elements, polarization	Distance from UTR-2 (LOFAR), km	Synthesis or VLBI resolution at 25 MHz
UTR-2	Kharkiv, RI NASU	8 - 32	140 000	2040, 1 linear	0 (~2000)	$25' \times 25'$
URAN-1	Zmiiv, RI NASU	8 - 32	5 500	96, 2 linear	42 (~1900)	15″
URAN-2	Poltava, PGO NASU	8 - 32	28 000	512, 2 linear	150 (~1800)	5″
URAN-3	Lviv, PMI NASU	8 - 32	14 000	256, 2 linear	915 (~1000)	1″
URAN-4	Odesa, RI NASU	8 - 32	7 300	128, 2 linear	613 (~1500)	1.3″

Konovalenko et al., 2015

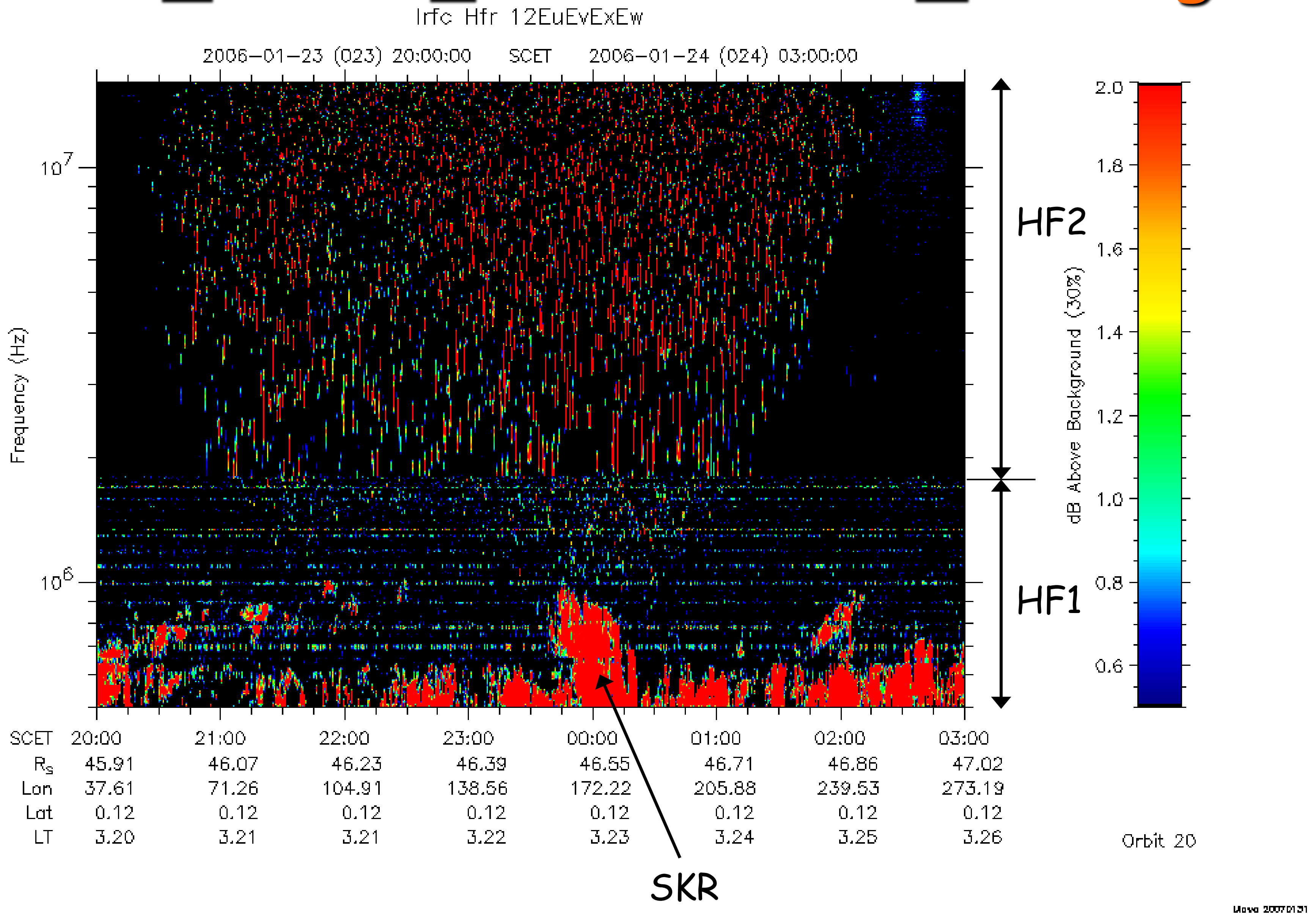
Konovalenko et al., 2015



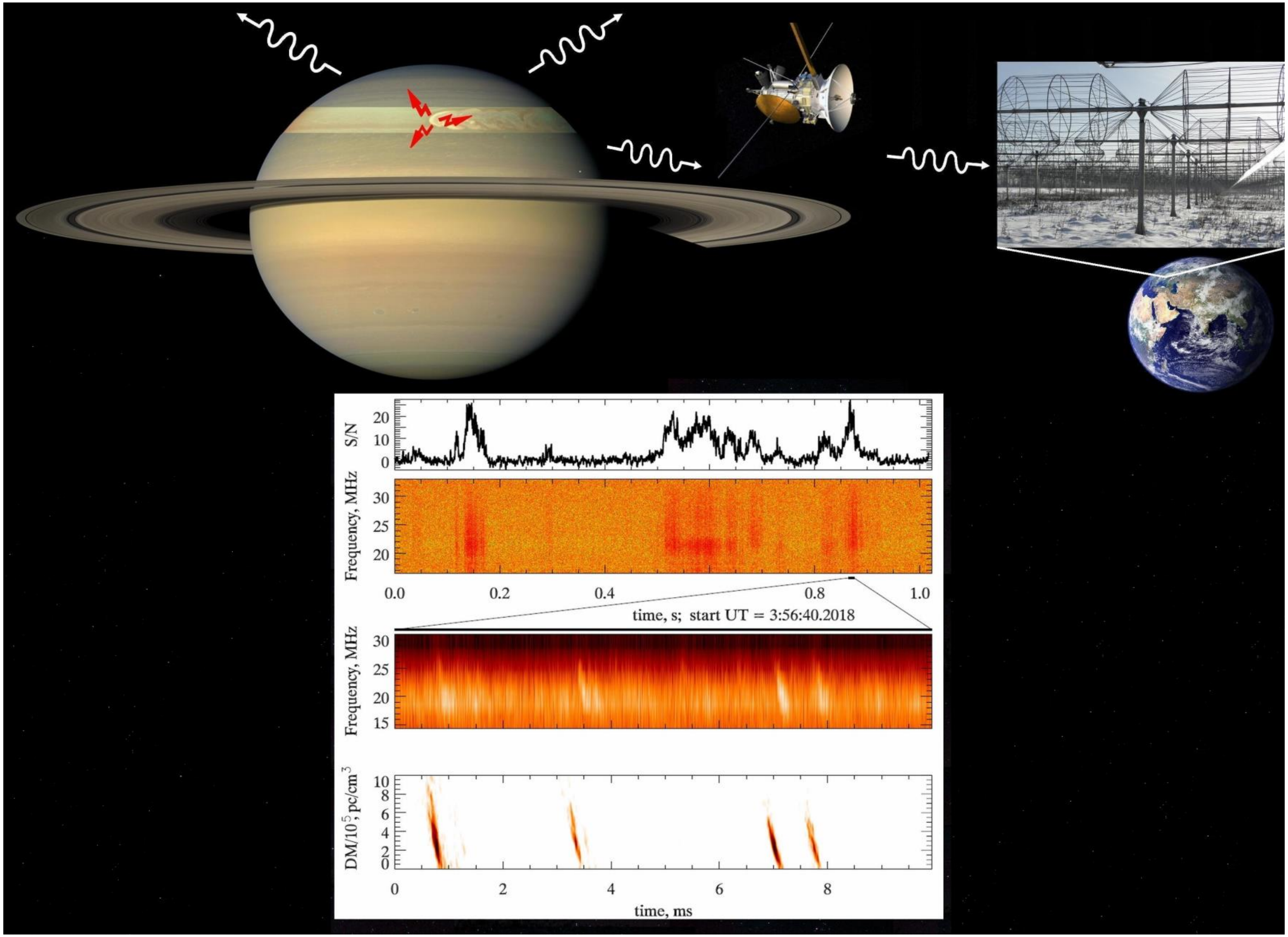

URAN-1…URAN-4 radio telescopes

Σ N (URAN) = 1000*2; Σ N (total) = 4040; Aeff (total) = 200000 sq. m

SEDs=Saturn Electrostatic Discharges

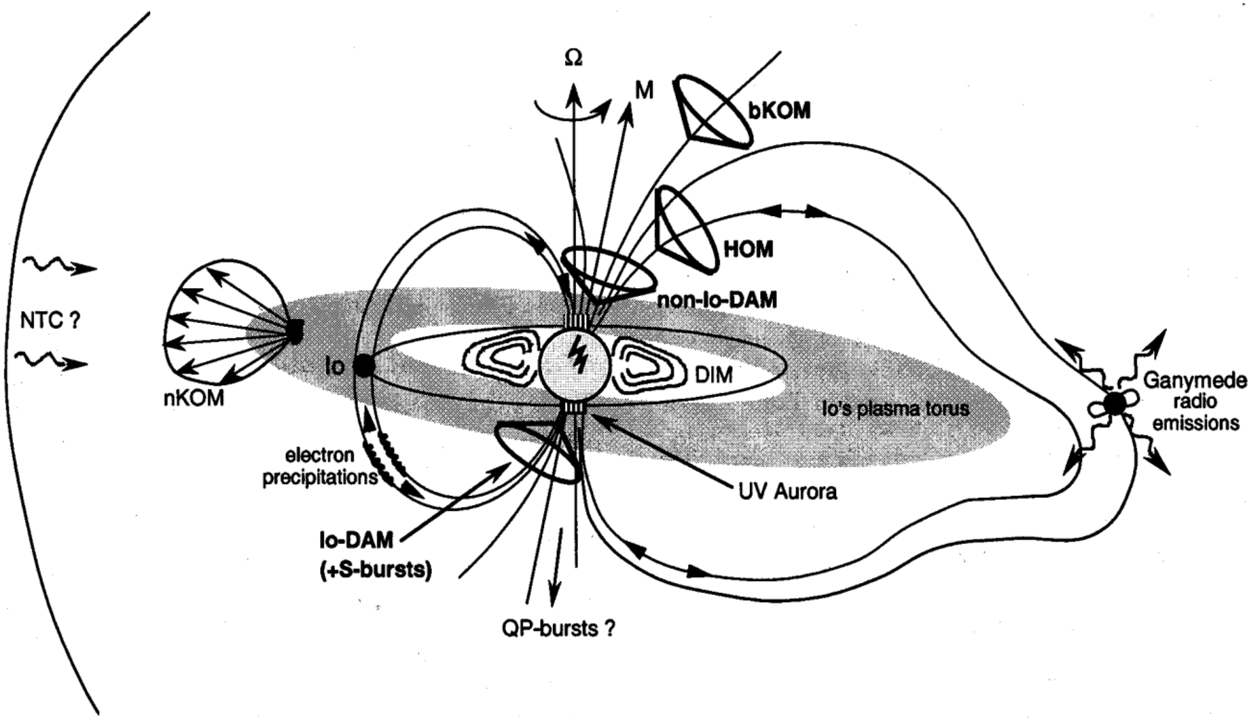


Ground-based detection and studies of the Saturn electrostatic discharges with the UTR-2



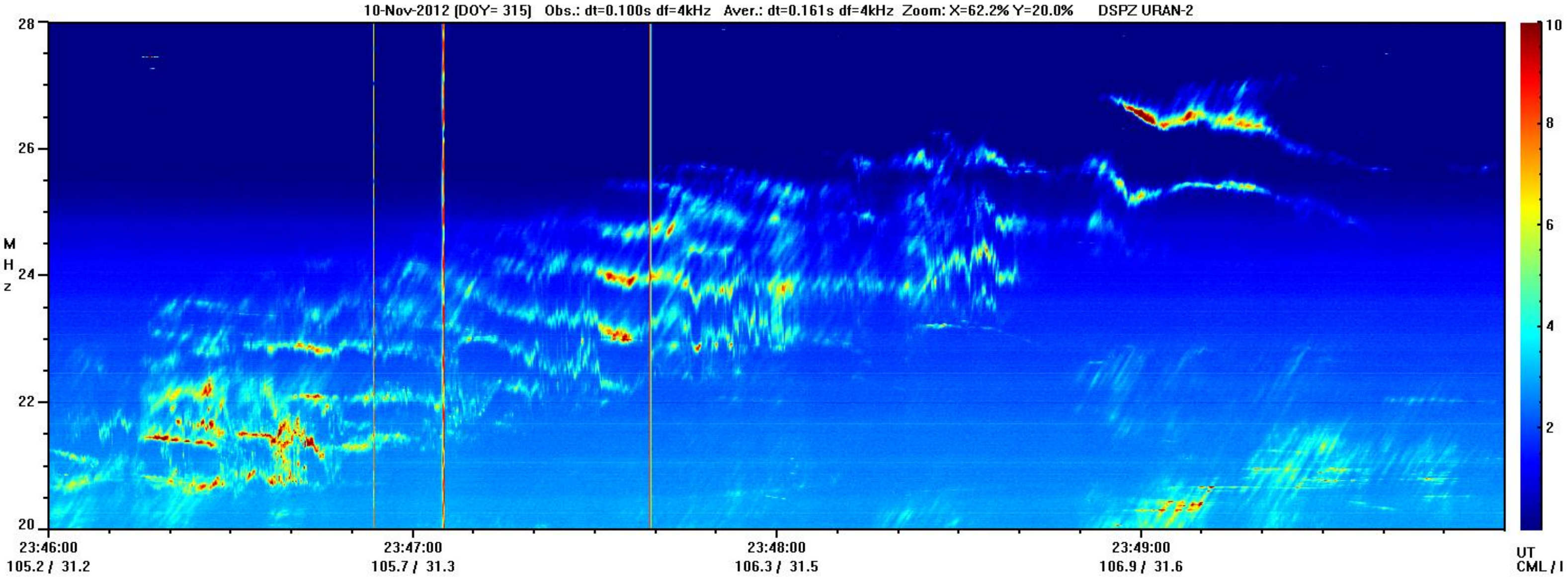
V. Zakharenko, C. Mylostna, A. Konovalenko, … H. Rucker et al.: Ground-based and spacecraft observations of lightning activity on Saturn, Planet. Space Sci., **61**,53-59, 2012.

Non-thermal radio waves originating from the Jovian magnetosphere



Recent detection (2015):
Zebra stripe-like patterns
in Jovian decametric frequency range

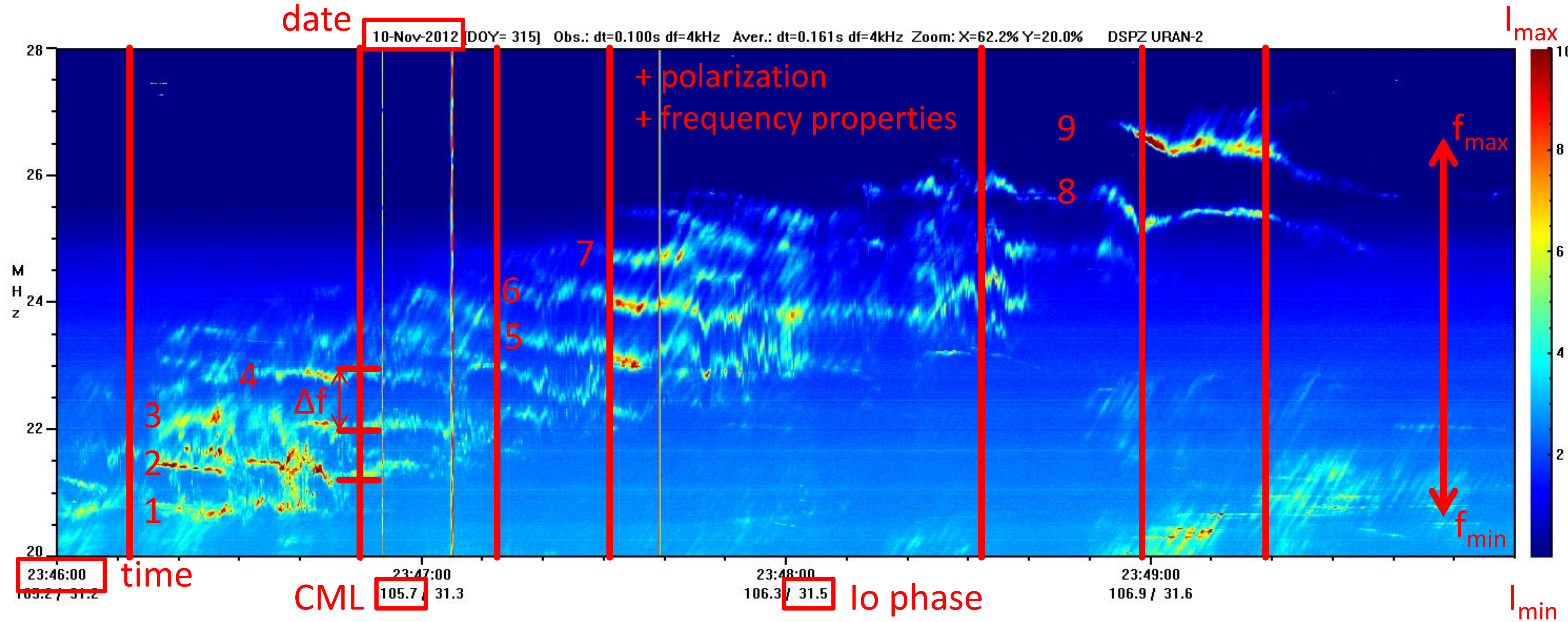
- Observations from URAN-2
- statistical analysis of Jovian zebra structures
  - CML, Io phase, polarization, frequency properties
  - basis for theoretical framework of Jovian zebra phenomenon



Rosker et al., 2015

Observations & data

- 44 most distinctive incidents in terms of high resolution and intensity selected
  - dynamic spectra
  - characterization of event
  - run of individual zebra stripes recorded (→ frequency properties)



Rosker et al., 2015

[3] A.J. Dessler, 1983

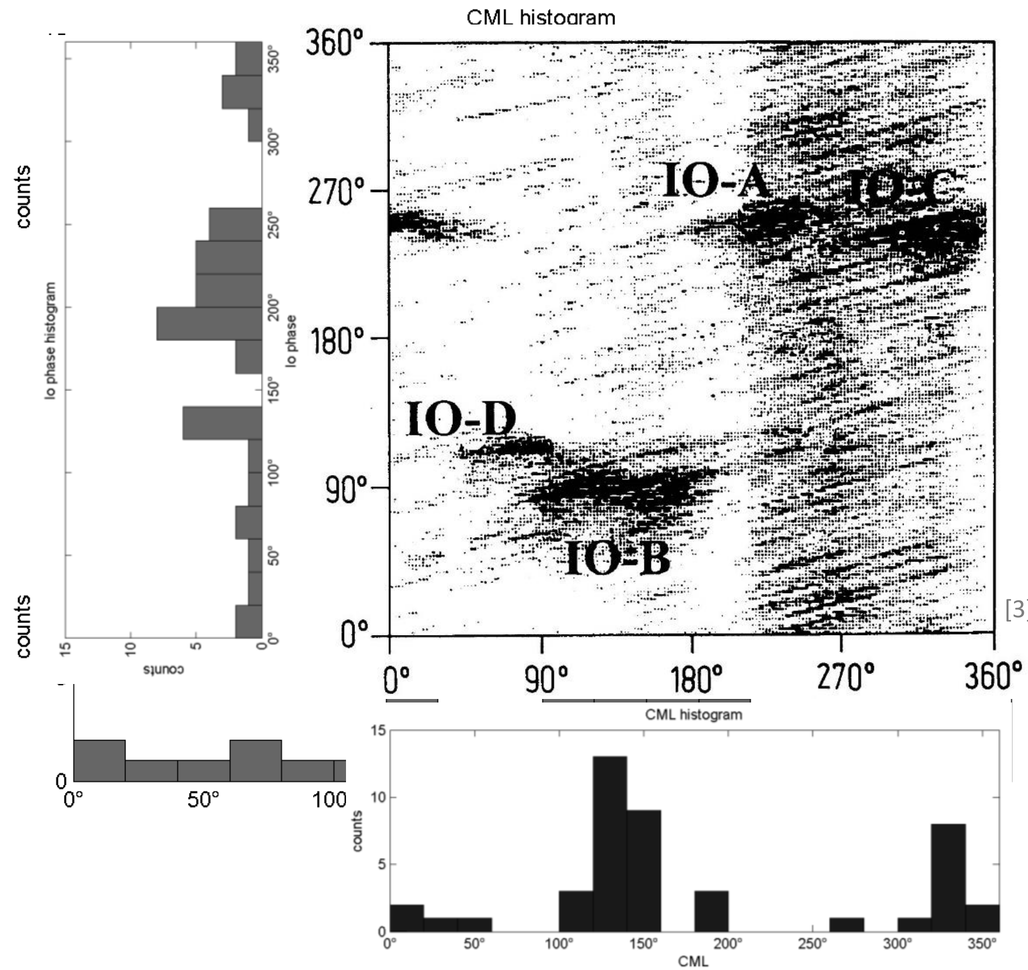
Occurrence distribution as functions of CML and Io phase

- "active" longitudes where emission of zebra structures more likely
- 2 regions of CML:
  - 300° to 60°
  - 100° to 160°

→ 2 active regions

- Io phase: zebra events controlled by Io

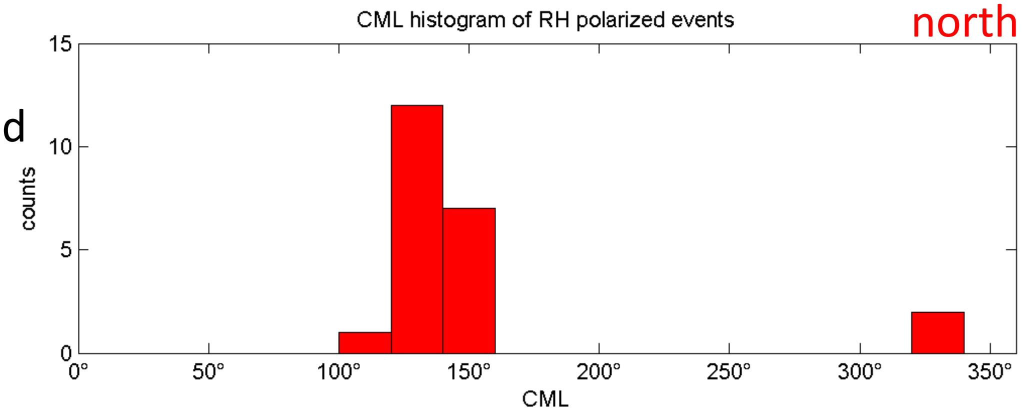
→ not controlled by Io

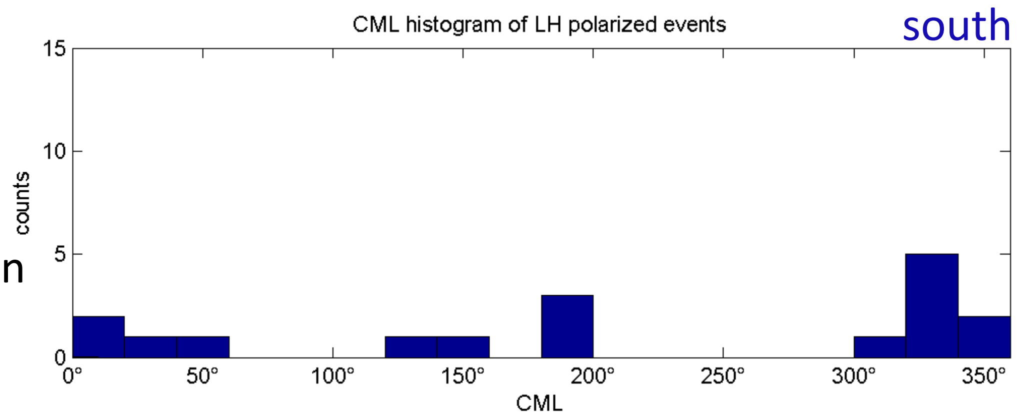


Rosker et al., 2015

Polarization

- separately visualizing the CML dependence of LH and RH polarized events
- 2 CML regions → assigned to a specific sense of polarization
  - 100° to 160° CML: RH pol.
  - 300° to 60° CML: LH pol.
- assuming RX-mode emission: possible to determine source region
  - RH → northern hemisphere
  - LH → southern hemisphere

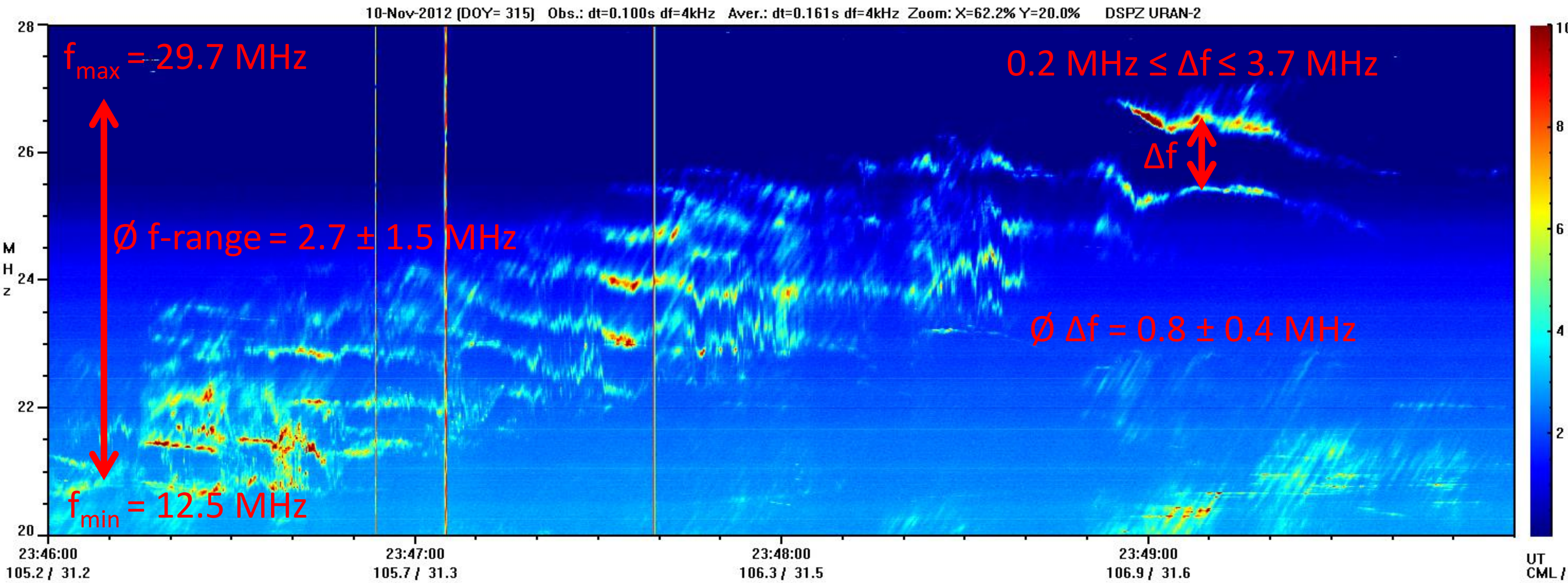




Rosker et al., 2015

Frequency properties

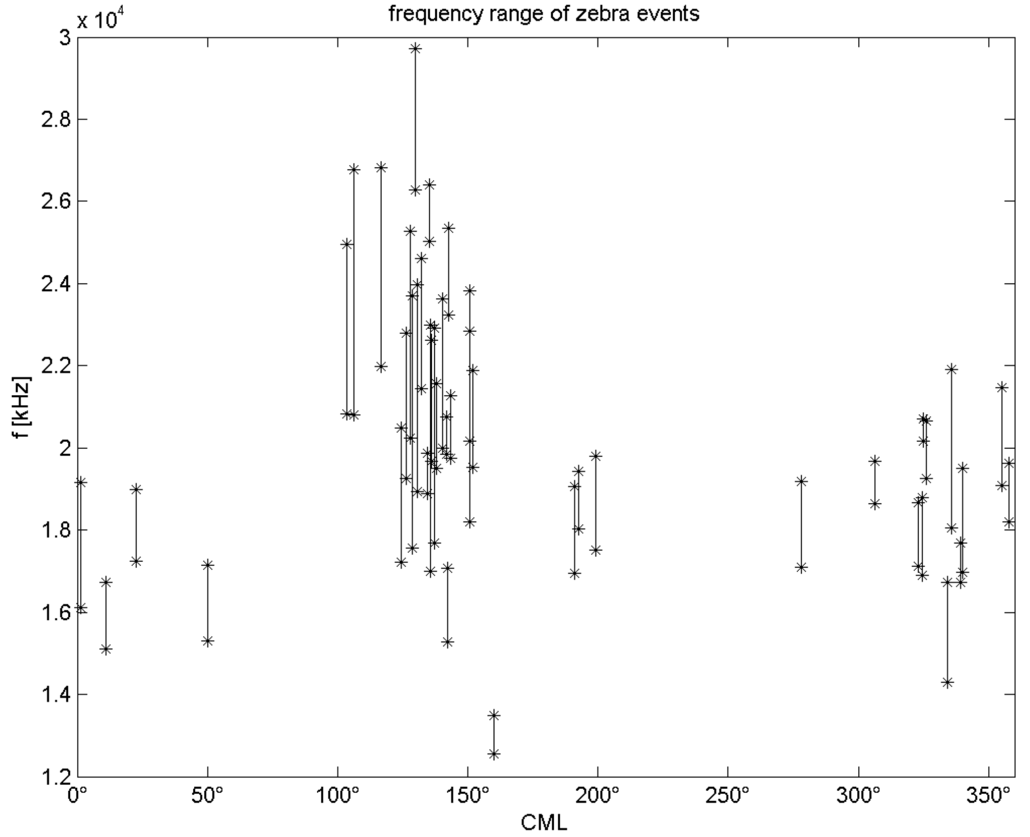
- overall frequency range: 12.5 MHz – ca. 29.7 MHz
  - mean range for 1 event: 2.7 ± 1.5 MHz
- frequency splitting: mean Δf = 0.8 ± 0.4 MHz
  - Δf_{min} = 0.2 MHz, Δf_{max} = 3.7 MHz
- frequency splitting increases with increasing frequency (72 % of cases)



Rosker et al., 2015

Frequency range – CML

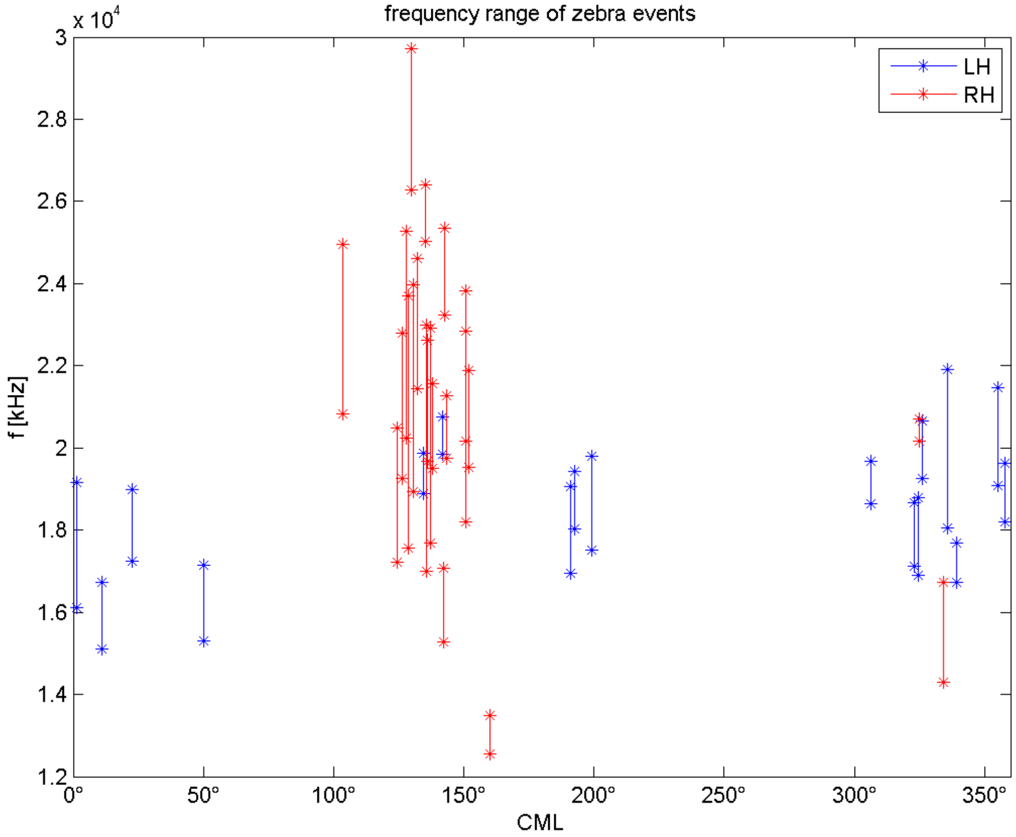
- 100° to 160° CML:
  - widespread events
  - events with larger number of stripes
  - events with higher frequency values



Rosker et al., 2015

Frequency range – polarization

- 100° to 160° CML:
  - widespread events
  - events with larger number of stripes
  - events with higher frequency values
  - mostly RH polarized
  - emerge from northern hemisphere
  - in accordance with stronger magnetic field strength in northern hemisphere

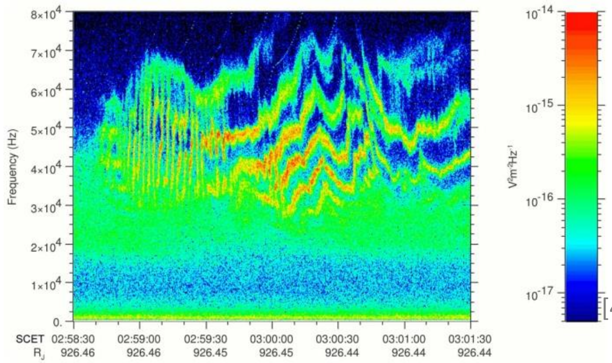


Rosker et al., 2015

[4] Kuznetsov & Vlasov, 2013
[5] Chernov, 2006
[6] Chernov, 2010
[7] Chen et al., 2011
[8] Ø. Elgarøy, 1961
[9] Kuznetsov & Tsap, 2007

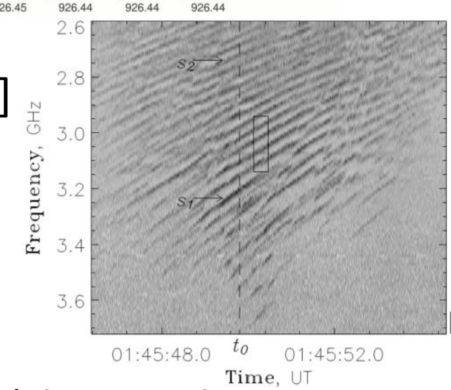
Possible generation mechanism

- similar phenomenon observed by Cassini during the Jupiter flyby 2000/2001
  - study on zebra pattern in low-frequency Jovian radio emission (tens of kHz) [4]
  - connected to solar zebra [5]-[7]



[4]

- zebra stripes first observed in radio spectra of Sun (1960ies) [8]
  - from ≈ 100 MHz to a few GHz
  - possible mechanism for wave generation: **double plasma resonance (DPR)**



[9]

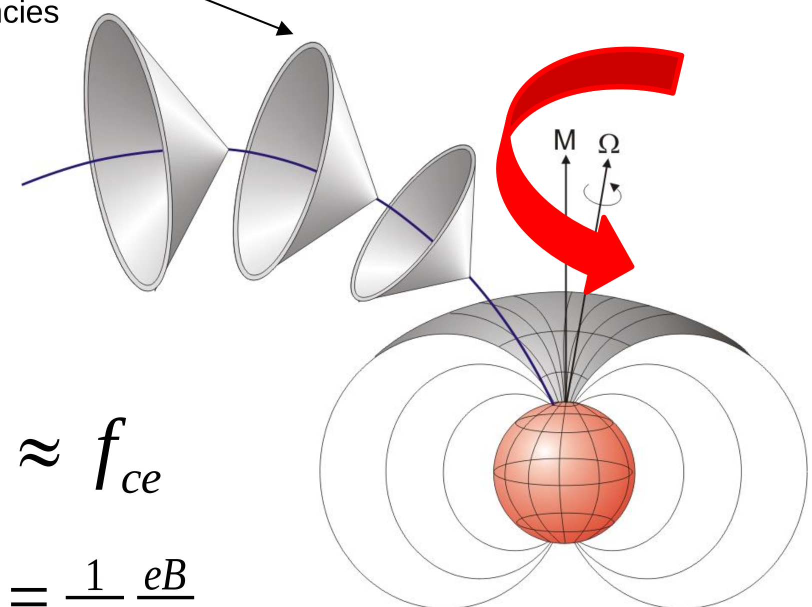
- generation efficiency of waves significantly higher if frequency (close to the upper hybrid frequency f_{uh}) is at harmonics of the electron cyclotron frequency f_c :

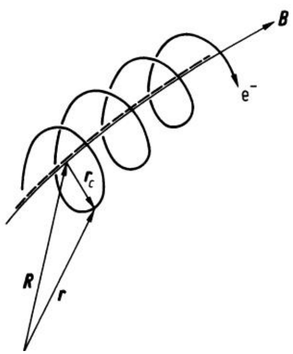
$$f_{uh} \cong s * f_c \qquad \text{with } s = 2,3,4, \ldots$$

- we use DPR as starting point for theoretical explanation of Jovian DAM zebra
  - for DPR of electrons very high plasma density required

Rosker et al., 2015

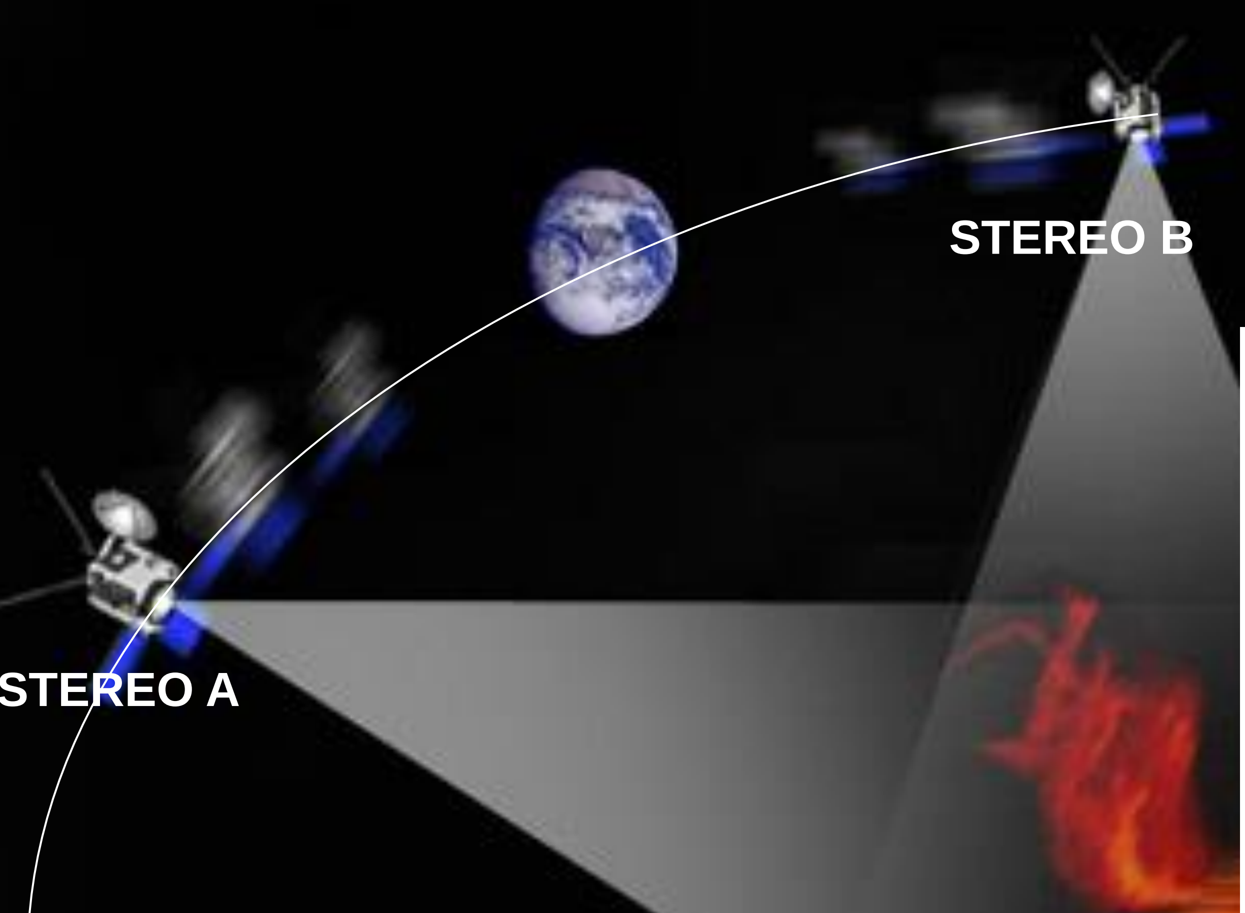
Jupiter DAM: Model of radio emission cone

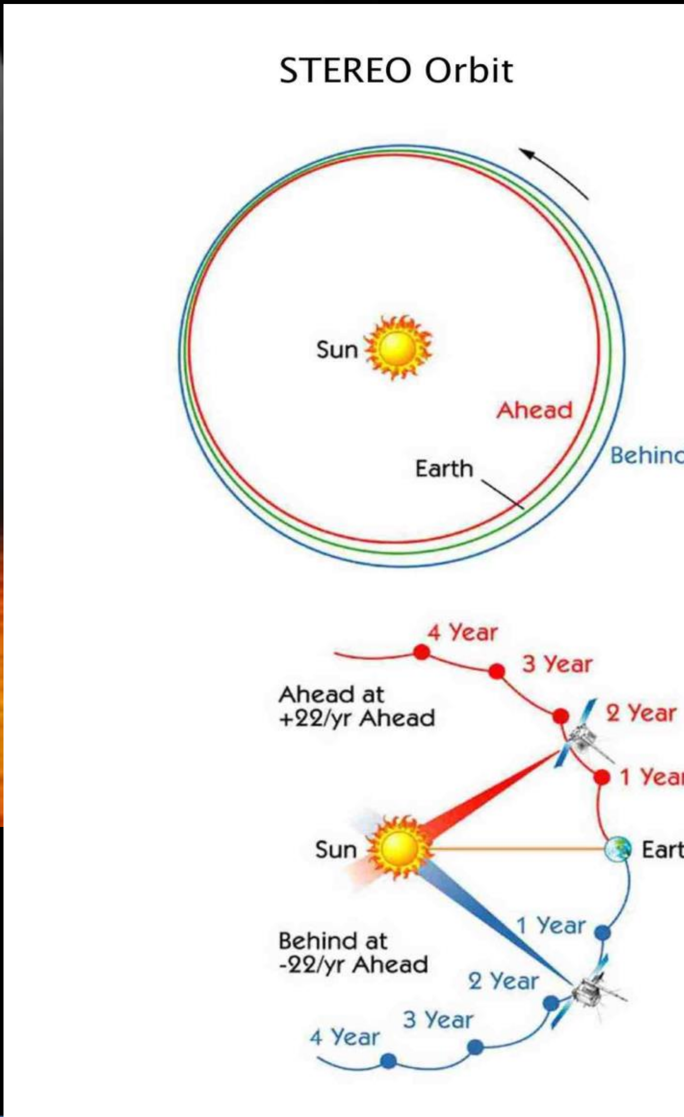




$$f \approx f_{ce}$$

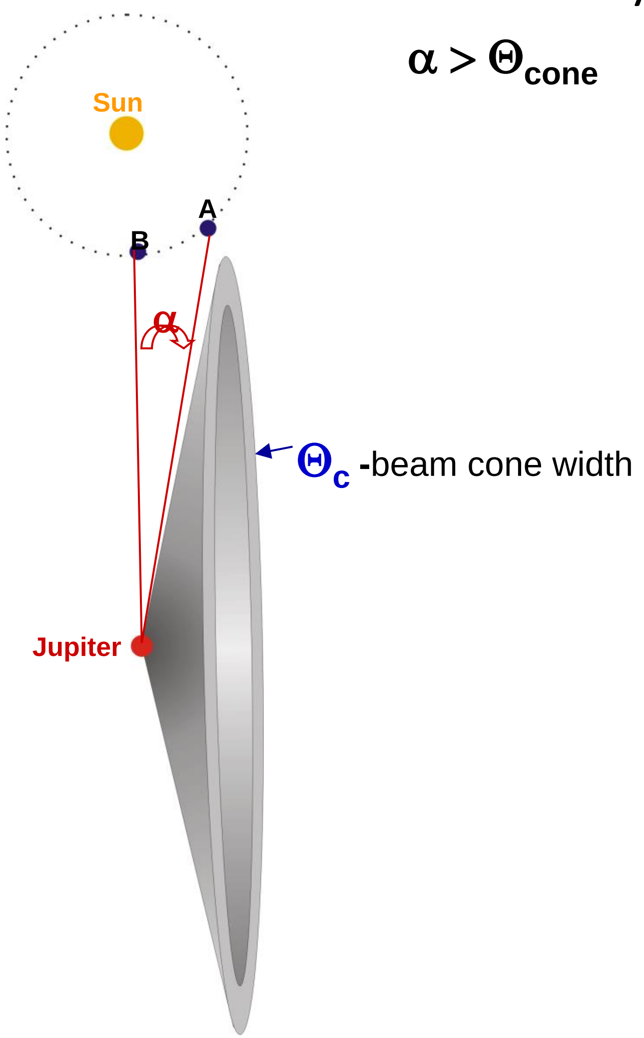
$$f_{ce} = \frac{1}{2\pi}\frac{eB}{m_e}$$

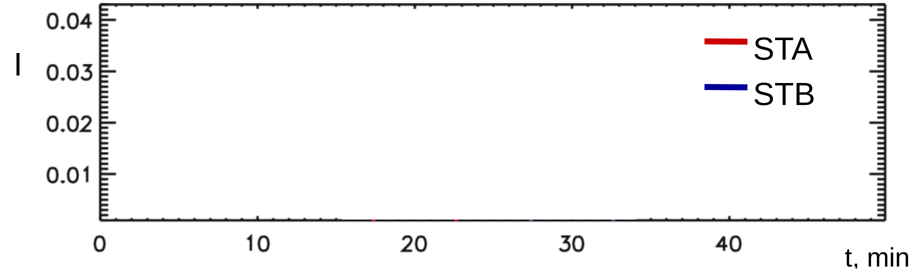

STEREO B
STEREO A


STEREO Orbit
Sun
Ahead
Behind
Earth
4 Year
3 Year
Ahead at
+22/yr Ahead
2 Year
1 Year
Sun
Earth
1 Year
Behind at
-22/yr Ahead
2 Year
3 Year
4 Year

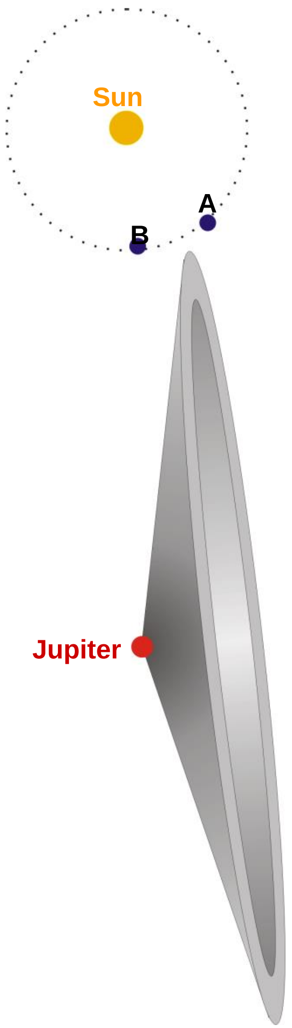
Stereoscopic observation of Jovian DAM by STEREO-A and -B

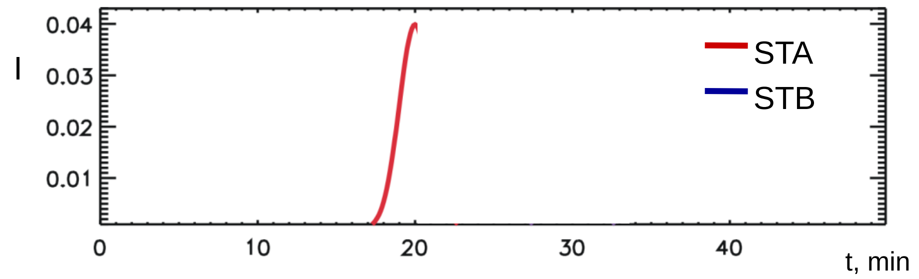
$\alpha > \Theta_{cone}$



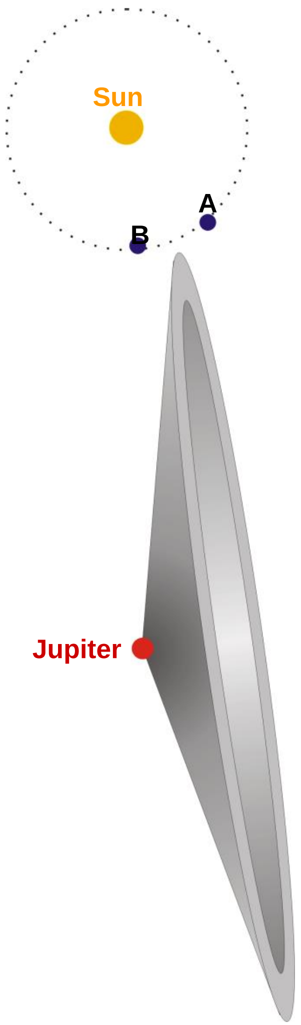


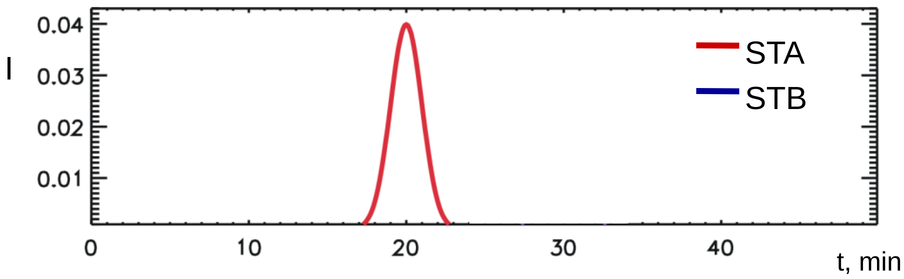
Stereoscopic observation of Jovian DAM
by STEREO-A and -B



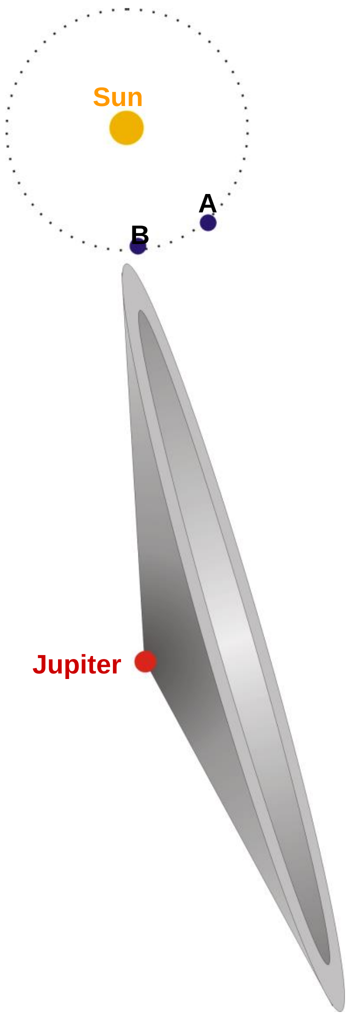


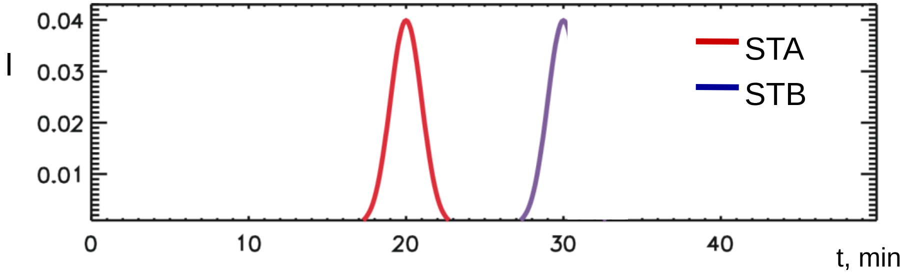
Stereoscopic observation of Jovian DAM by STEREO-A and -B





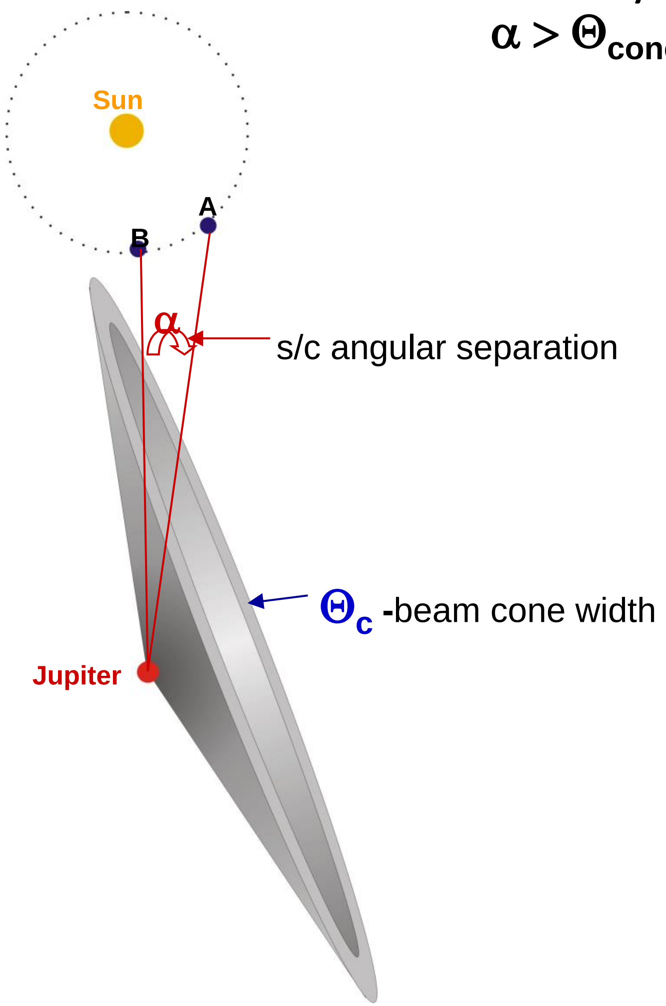
Stereoscopic observation of Jovian DAM by STEREO-A and -B

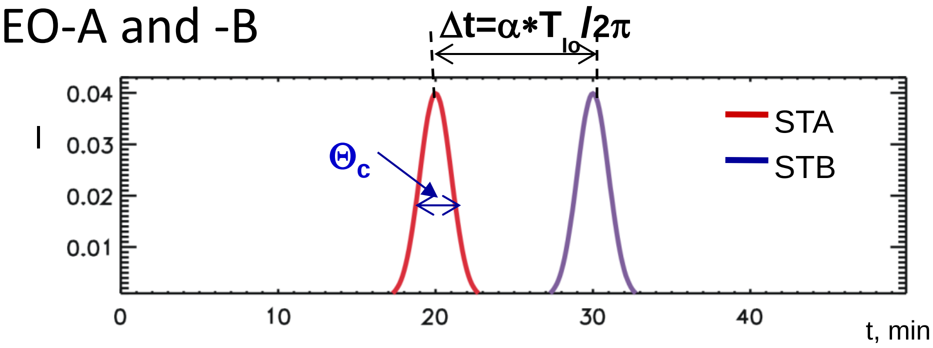




Stereoscopic observation of Jovian DAM by STEREO-A and -B

$\alpha > \Theta_{cone}$





Emission cone width:

Io-C: 1.07° – 1.12° (22 episodes)

Io-D: 0.96° – 1.08° (24 episodes)

non-Io: 1.11° – 1.13° (21 episodes)

(Panchenko et al., 2010)

(Zörweg, Diploma thesis, 2011)

Summary:

- Ground-based planetary radio astronomy yields new discoveries due to increasing sensitivity of radio telescopes, increasing antenna arrays, and improved backend facilities

- Space-borne planetary radio astronomy yields new possibilities due to stereoscopic observations

- The combination of both ground-based and space-borne observations of solar, heliospheric, and planetary radio emission is thus the goal for present and future solar system radio astronomy